Strong mothers bear more sons in rural Ethiopia

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In humans, there is evidence that the physiological cost to the mother of bearing sons is greater than of bearing daughters. Parents should manipulate the sex of offspring born in response to resource availability to maximize their reproductive success. Here, we demonstrate that, within a rural food-stressed community in southern Ethiopia, there is a strong association between the sex of the most recent birth and maternal nutritional status, measured either by body mass index or mid-upper arm muscle area (AMA) (measures of fat and muscle mass). The effect of muscle mass is very marked: those women in the upper 25th percentile of AMA were more than twice as likely to have had a recent male birth than those in the lowest 25th percentile.

Keywords: sex ratios; parental investment; maternal condition; human nutrition

1. INTRODUCTION

In humans, there is evidence that the physiological cost to the mother of bearing sons is greater than of bearing daughters (Marsal 1996; Mace & Sear 1997; Loos *et al.* 2001), which may lead to shorter maternal lifespans after male birth (Beise & Voland 2002; Helle *et al.* 2002). Malnourished males suffer higher intra-uterine and infant mortality than females (Wells 2000), grow into adults of short stature (Barker 1992) who may be more disadvantaged in finding mates (Phillips *et al.* 2001), thereby experiencing lower reproductive success in both modern and traditional populations (Hill & Hurtado 1996; Pawlowski *et al.* 2000; Mueller & Mazur 2001). Parents should manipulate the sex of their offspring in response to resource availability in order to maximize their reproductive success (Trivers & Willard 1973). Experimental and observational animal studies have demonstrated a facultative adjustment in sex ratio at birth in response to maternal physical condition (Rivers & Crawford 1974; Clutton-Brock & Iason 1986; Nager *et al.* 1999); however, there is no clear supporting evidence from human populations. There is some evidence that male foetuses are more susceptible to exposure to toxic substances, but results on the effect of maternal nutritional condition on sex ratio are inconclusive (Lazarus 2002).

Here, we demonstrate that, within a rural food-stressed community in southern Ethiopia, there is a strong association between the sex of the most recent birth and maternal nutritional status, measured either by body mass index (BMI) or mid-upper arm muscle area (AMA) (measures of fat and muscle mass; Gurney & Jelliffe 1973). Both measures are highly significantly associated with sex ratio but the effect of muscle mass is very marked: those women in the upper 25th percentile of AMA were more than twice as likely to have had a recent male birth than those in the lowest 25th percentile.

2. MATERIAL AND METHODS

Demographic and anthropometric data for the analyses were collected from an Oromo agro-pastoralist community in Arsi zone, southern Ethiopia, during the dry season in 2000. The region suffers from irregular rainfall, and during 1999–2000 this resulted in widespread crop failure and acute food shortages (USAID-FEWS NET 2000). About 20% of adult females suffered from chronic energy deficiency (BMI less than 18.5). A birth-history calendar recording the monthly timing of reproductive events over the 5 years preceding the interview was collated for 324 married women below 50 years of age. Each woman was also measured for height, weight, mid-upper arm circumference and triceps skinfold thickness.

3. RESULTS

Figure 1 shows the relationship between AMA and the sex of the most recent birth. Multivariate logistic regression analyses identified that maternal AMA was very significantly correlated with the sex of the last child ($\beta = 0.08$, s.e. $= 0.02$, $p = 0.0005$), whereas the mother's age, parity, year of birth and the time lapsed between the birth and anthropometric measurement (within 5 years) had no effect. A similar result was identified when either maternal BMI ($\beta = 0.167$, s.e. $= 0.06$, $p = 0.005$) or mid-upper arm circumference ($\beta = 0.187$, s.e. $= 0.06$, $p = 0.001$) were used as the measure of nutritional status; however, there was no independent effect of height. AMA, mid-upper arm circumference and BMI are all highly correlated in this population, where the majority of individuals carry rather little body fat. Overall, fewer males were born during the study period (sex ratio: 0.88), which may imply male-biased foetal loss. Males also had a higher monthly risk of dying than the females during childhood (below 5 years of age) ($\beta = 0.457$, s.e. $= 0.22$, $p < 0.05$).

4. DISCUSSION

The few studies of the relationship between nutritional deficiencies and sex-ratio biasing in humans have not found consistent evidence of an association (Williams & Gloster 1992; Andersson & Bergstrom 1998). This may be partly because they have used BMI as a measure of maternal condition. In most adequately nourished populations, because BMI reflects both fat and muscle mass, this measure cannot differentiate between women who are fat and those who are muscular. Stresses to the foetus in well-nourished populations are shown to be related not to maternal malnutrition but to other aspects of socioeconomic and health status, such as obesity (Andersson & Bergstrom 1998), smoking (Fukuda *et al.* 2002) or environmental pollution (Williams *et al.* 1992). However, our results indicate that in a human population subject to periodic severe food shortages and high physical workloads, there is marked facultative sex-ratio adjustment by mothers in relation to their physical strength.
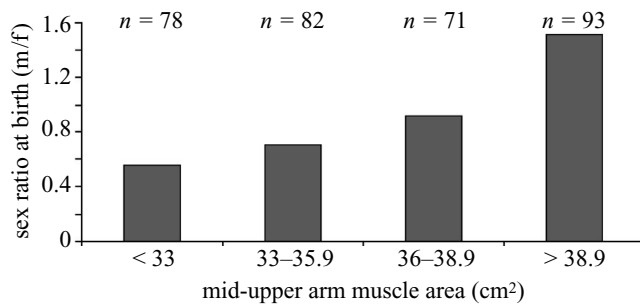
Figure 1. Sex ratio of the most recent birth for women by maternal mid-upper AMA ($n = 324$; overall sex ratio, 0.88). AMA is calculated by using mid-upper circumference and triceps skinfold thickness (AMA = (arm circumference $- (\pi \times \text{triceps skinfold}))^2/4\pi)^{16}$.

Andersson, R. & Bergstrom, S. 1998 Is maternal malnutrition associated with a low sex ratio at birth? *Hum. Biol.* **70**, 1101–1106.

Barker, D. J. P. 1992 *Foetal origins of adult disease*. London: British Medical Journal.

Beise, J. & Voland, E. 2002 Effect of producing sons on maternal longevity in premodern populations. (In technical comments). *Science* **298**, 317a.

Clutton-Brock, T. H. & Iason, G. R. 1986 Sex ratio variation in mammals. *Q. Rev. Biol.* **61**, 339–374.

Fukuda, M., Fukuda, K., Shimizu, T., Andersen, C. Y. & Byskov, A. G. 2002 Parental periconceptional smoking and male : female ratio of newborn infants. *The Lancet* **359**, 1407–1408.

Gurney, J. M. & Jelliffe, D. B. 1973 Arm anthropometry in nutritional assessment: nomogram for the rapid calculation of muscle circumference and cross-sectional muscle and fat areas. *Am. J. Clin. Nutr.* **26**, 912–915.

Helle, S., Lummaa, V. & Jokela, J. 2002 Sons reduced maternal longevity in preindustrial humans. *Science* **296**, 1085.

Hill, K. & Hurtado, A. M. 1996 *Ache life history*. New York: Aldine.

Lazarus, J. 2002 Human sex ratios: adaptations and mechanisms, problems and prospects. In *Sex ratios: concepts and research methods* (ed. I. C. W. Hardy), pp. 287–311. Cambridge University Press.

Loos, R. J. F., Derom, C., Eeckels, R., Derom, R. & Vlietinck, R. 2001 Length of gestation and birthweight in dizygotic twins. *The Lancet* **358**, 560–561.

Mace, R. & Sear, R. 1997 Birth interval and sex of children in a traditional African population: an evolutionary analysis. *J. Biosoc. Sci.* **29**, 499–507.

Marsal, K. 1996 Intrauterine growth curves based on ultrasonically estimated foetal weights. *Acta Paediatr.* **85**, 843–848.

Mueller, U. & Mazur, A. 2001 Evidence of unconstrained directional selection for male tallness. *Behav. Ecol. Sociobiol.* **50**, 302–311.

Nager, R. G., Monaghan, P., Griffiths, R., Houston, D. C. & Dawson, R. 1999 Experimental demonstration that offspring sex ratio varies with maternal condition. *Proc. Natl Acad. Sci. USA* **96**, 570–573.

Pawlowski, B., Dunbar, R. I. M. & Lipowicz, A. 2000 Evolutionary fitness: tall men have more reproductive success. *Nature* **403**, 156.

Phillips, D. I. W. *et al.* 2001 Prenatal growth and subsequent marital status: longitudinal study. *Br. Medical J.* **322**, 771.

Rivers, J. P. W. & Crawford, M. A. 1974 Maternal nutrition and the sex ratio at birth. *Nature* **252**, 297–298.

Trivers, R. L. & Willard, D. 1973 Natural selection of parental ability to vary the sex ratio of offspring. *Science* **179**, 90–92.

USAID-FEWS NET 2000 Ethiopia food security update (July). See www.fews.net.

Wells, J. C. K. 2000 Natural selection and sex differences in morbidity and mortality in early life. *J. Theor. Biol.* **202**, 65–76.

Williams, F. L. R., Lawson, A. B. & Lloyd, O. L. 1992 Low sex-ratios of births in areas at risk from air-pollution from incinerators, as shown by geographical analysis and 3-dimensional mapping. *Int. J. Epidemiol.* **21**, 311–319.

Williams, R. J. & Gloster, S. P. 1992 Human sex-ratio as it relates to caloric availability. *Social Biol.* **39**, 285–291.